Appendectomy as Teaching Operation: No Compromise in Safety-An Audit of 17,106 Patients

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Abstract: OBJECTIVE In a surgical career, teaching of surgical procedures plays a central role. In this study we want to evaluate the influence of teaching in appendectomies on the in-hospital outcome. DESIGN AND SETTING Retrospectively, 26,436 cases from the national quality measurement database (AQC) between the years 2009 and 2017 were evaluated using the diagnosis and the procedure codes. Included were all cases with appendicitis (International Classification of Diseases diagnostic codes K35-K37), surgical treatment (appendectomy), and a documented teaching status of the procedure. Variables were sought in bivariate and multivariate analyses. The occurrence of any complication was the primary outcome, whereas in-hospital mortality was the secondary outcome. PARTICIPANTS A total of 17,106 patients with a mean age of 37 ± 19 years remained for final analysis. A total of 6267 operations (37%), were conducted as teaching-operations. Seventy-four percent of all teaching procedures were performed by residents. RESULTS We found no statistical association between teaching operations and complication rates or mortality. However, the teaching group showed longer duration of surgery (+ 11%). CONCLUSIONS There was no influence of the training status of the appendectomy procedure on complication rates and in-hospital mortality. However, there was a prolonged duration of surgery. Despite these statistically significant differences, a comparable clinical outcome was observed in all patients, thus justifying the benefits of resident training.

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Appendectomy as Teaching Operation: No Compromise in Safety—An Audit of 17,106 Patients

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KEY WORDS: Appendectomy, In-hospital, Outcome, Teaching

COMPETENCIES: Patient Care, Medical Knowledge, Professionalism, Practice-Based Learning and Improvement

INTRODUCTION

Teaching of residents in the operating room remains a fundamental part of surgical education to ensure continuous high-quality patient care.[1−3] Traditionally, surgical trainees learn by observing and imitating the work of an experienced surgeon, which is called the "apprenticeship model" of training.[4,5] In order to gain expertise from this teaching model, a large number of cases with opportunities for repetition, highly skilled mentors and long working hours are required.[6] Young surgeons receive a large portion of their teaching assisting experienced surgeons in emergency operations.[7,8] Teaching in surgery in Switzerland is not reimbursed and not structured uniformly.[9−14]

Acute appendicitis remains one of the most common surgically treated diseases worldwide with an incidence ranging from 160/100,000 person-years in the Middle East to 206/100,000 person-years in Asia.[15,16] In Switzerland, up to 10,000 appendectomies are performed per year.[17,18]

Open as well as laparoscopic appendectomies serve as good teaching procedures for young surgeons and are typically performed by general surgery residents.[19,20] The aim of our present study was to evaluate whether appendectomies in the setting of a teaching situation in

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Switzerland have an effect on the short-term in-hospital outcome of patients.

METHODS

Study design and setting

The Swiss Association for quality assessment in surgery (Arbeitsgemeinschaft für Qualitätssicherung in der Chirurgie—AQC[21]) prospectively collects data of surgical inpatients since more than 20 years. Sixty-eight percent of the surgical departments in Switzerland (n = 96) participate in this large registry.

We distinguish university (n = 5), primary care level 2 (n = 39), level 3 (n = 15), level 4 (n = 27), as well as private hospitals (n = 35). Typically, the private hospitals are nonteaching hospitals and the rest are teaching hospitals. In the AQC database, we have data from both types of hospitals, however mostly (90%) from designated teaching hospitals. Only de-identified data from this registry was used in this study; hence our institutional review board (IRB) decided the study to be exempt from institutional review board approval.

Participants/Study subjects

Data of all surgical inpatients prospectively documented between January 1, 2009 and December 31, 2017 were used in this study. Inclusion criteria were acute appendicitis (diagnostic codes K35 to K37 based on the World Health Organization's *International Statistical Classification of Diseases and Related Health Problems* (ICD-10[22]). Furthermore, patients must have been operated and the teaching status of this procedure must have been reported. Among 18,593 patients, 17,106 demonstrated a complete data set and were included.

Variables, outcome measures, data sources and bias

Two questionnaires exist within AQC-database. One questionnaire provides demographic patient data including age, gender, ASA-score (American Society of Anesthesiologists physical status classification system), type of admission (registered/planned or emergency), insurance status (private versus statutory insurance coverage), length of hospital stay, length of intensive care unit (ICU) stay, comorbidities, the need for reintubation and discharge status (death, home, nursing home, retirement home, rehabilitation facility, and others).

The other part of the questionnaire provides information about the surgical procedure: level of training of the surgeon divided into 3 groups (senior attending, junior attending, and residents), type of surgery (laparoscopic, open, or conversion from laparoscopy to open), duration of surgery, occurrence of complications (intra- and postoperative), teaching status of the operation, thromboembolism prophylaxis, and the use of antibiotics.

It is important to note that all Swiss inhabitants are required to have statutory health insurance. This statutory health insurance can be supplemented by a semiprivate or private insurance policy that gives access to more extensive coverage (operation done by seniors, single room) than basic health insurance.

Teaching of a procedure is defined as an operation in which a less experienced surgeon (usually a resident) performs the whole operation or the relevant steps under supervision of a more experienced colleague (usually a junior attending). Typically, the teaching operations are performed by residents in training and supervised by a junior or senior attending. However, residents in the last 1 to 2 years of their training are promoted on a regular basis to a junior attending to gain faster and more experience and get their surgical specialization. In these situations, also a new junior attending can perform the teaching operation under the supervision of a senior attending surgeon.

The decision whether an operation is performed as a teaching procedure or not is made directly by the attending on call. The severity of the disease, the insurance status, and the experience of the residents are all factors contributing to this decision.

In Switzerland the surgical training consists of 2 years of basic training and is followed by a 4-year advanced training period. This further training can take place in various special disciplines However, 3 main tracks are possible: mainly abdominal, general, or trauma (extremities). Two out of these years have to be performed in a large hospital and 1 year in a smaller hospital. Also, a 3 to 6 months rotation in the emergency department and ICU is mandatory.

Occurrence of any in-hospital complications (intra- and postoperative), was the primary outcome measure. Secondary outcome measures were in-hospital mortality.

Statistical analysis

With the Adjumed Analyze tool (Adjumed Services AG, Zurich, Switzerland) all data were extracted online and further analyzed by using the Statistical Package for Social Sciences (SPSS Statistics program, Version 24, IBM software Corp., Armonk, New York).

Continuous data were expressed as mean and standard deviation, numbers and categorical data in absolute and relative numbers.

Chi-square and Fisher tests, where applicable, were used for bivariate categorical analysis. We found no normal distribution in the continuous data with the Kolmogorov-

Smirnov test. Therefore, continuous data were compared with the Mann-Whitney *U* test in bivariate analysis.

We performed only bivariate analysis with predictors for mortality due to the expected low mortality.

Risk factors for complications and predictors for teaching were evaluated as confounders in a stepwise backward likelihood logistic regression analysis. Significant ($p < 0.05$) or nearly significant factors ($p < 0.1$) in bivariate analysis were chosen as potential (independent) risk factors and were entered in a logistic regression analysis with "occurrence of any complications" as the dependent. A p value of <0.05 was considered statistically significant. The R square value from the logistic regression analysis output was used to calculate the variation.

RESULTS

Description of the study population

A total of 17,106 patients with a mean age of 37 ± 19 years remained for final analysis. Fifty-three percent of the patients were male and 47% female. Ninety-seven percent of our cases were admitted as emergencies. Thirty-eight percent of patients had an ASA-Score of II (mild systemic disease). Eighty-six percent of the operations were successfully completed laparoscopically. A conversion from laparoscopic to open surgery was necessary in 11% of all cases. The average length of stay was 3.5 ± 3.8 days. Twenty-nine patients (0.17%) died during the hospital stay. Complications occurred in 4.7% of all cases (Table 1).

Teaching procedures

A total of 6267 operations (37%), were conducted as teaching-operations. Seventy-four percent of all teaching procedures were performed by residents in training. Patients with a teaching intervention had a slightly lower ASA-score, fewer comorbidities and were more often covered by statutory healthcare insurance. The average duration of surgery was significantly longer in the teaching group compared with the nonteaching group (69 ± 48 vs. 62 ± 46 minutes $p < 0.001$) (Table 2).

Complications

Complications occurred in 4.7% of our cases (5.0% in the nonteaching and 4.3% in the teaching group, $p = 0.025$). The most common complications were: urinary retention, paralytic ileus, pneumonia and iatrogenic blood vessel injury. We found only small and not significant differences concerning the complication rates that might be attributed to resident involvement (e.g. iatrogenic injury to a blood vessel 0.2% in the teaching group vs. 0.1% in the nonteaching group).

While controlling for confounders, teaching of a procedure did not increase the rate of complications and was removed from the multivariate model. A higher ASA-score, the need for anticoagulation versus thromboembolism prophylaxis, open or conversion versus laparoscopic surgery, presence of comorbidities, need for reintubation, longer length of stay preoperative and in the ICU, higher age, and longer duration of surgery were significant predictors of complications. The regression model explained 18% of the variation ($R^2 = 0.18$). (Table 3)

Mortality

The overall mortality rate was 0.17% (0.17% in the nonteaching and 0.18% in the teaching group); teaching was not a significant parameter in the bivariate analysis ($p = 0.089$). Higher age, higher ASA score, longer preoperative length of stay, longer stay in the ICU, the need for reintubation, open surgery versus laparoscopic surgery, the occurrence of complications, the need for an antibiotic therapy and an appendicitis with generalized peritonitis were associated with higher mortality during the hospitalization (Table 4). Multivariate regression analysis was not possible due to the small numbers of death.

Teaching

Predictors for teaching were: statutory insurance status vs. private insurance status, conversion or open versus laparoscopic surgery, absence of comorbidities, appendicitis with localized peritonitis vs. acute appendicitis with peritoneal abscess, and younger age. The regression model explained 10% of the variation ($R^2 = 0.10$) (Table 5).

DISCUSSION

The rising demand for cost-effectiveness and the introduction of working hour limitations has changed teaching habits in the general surgery curriculum. In the present study, we tried to assess if an appendectomy performed by a resident or fellow (junior attending) in training was a predictor for complications and in-hospital mortality.

The large sample size enabled us to control for co-factors. Furthermore, the nationwide data collection gives us a broad, representative patient population. However, the present study has some limitations. Generally, the quality of registry data (AQC) is considered inferior due to a lack of data verification. Second, we received de-identified data, which did not allow us to complete missing data. Another disadvantage of registry data is that data quality is dependent on the physician performing

TABLE 1. Teaching YES or NO; Patient Characteristics

Parameter		Teaching NO (n = 10,839)		Teaching YES (n = 6267)		p Value
		n	%	N	%	
Age (years)	Mean ± SD	39 ± 20		35 ± 18		<0.001
Gender	Male	5685	52	3347	53	n.s.
	Female	5154	48	2920	47	
ASA	I (Healthy person)	6147	57	3717	59	<0.001
	II (Mild systemic disease)	4098	38	2310	37	
	III (Severe systemic disease)	565	5.2	230	3.7	
	IV (Severe systemic disease that is a constant threat to life)	26	0.24	10	0.16	
	V (Moribund person who is not expected to survive without the operation)	3	0.028	0	0	
Admission type	Emergency	10465	97	6053	97	n.s.
	Registered, planned	374	3.5	214	3.4	
Insurance	Statutory	8576	79	5931	95	<0.001
	Private	2263	21	336	5.4	
Length of stay (days)	Mean ± SD	3.6 ± 4.0		3.2±3.6		<0.001
Length of stay preoperative (days)	Mean ± SD	0.36 ± 1.1		0.37±0.97		n.s.
Length of stay postoperative (days)	Mean ± SD	3.3 ± 3.7		2.9±3.3		<0.001
Duration ICU (hours)	Mean ± SD	0.92 ± 16		0.83±16		n.s.
Comorbidity	Yes	643	5.9	243	3.9	<0.001
Intubation	Yes	357	3.3	137	2.2	<0.001
Discharge	Deceased	18	0.17	11	0.18	0.022
	At home	10,537	97	6139	98	
	Nursing home	30	0.28	19	0.30	
	Retirement home	28	0.26	15	0.24	
	Rehabilitation facility	27	0.25	9	0.14	
	Other	199	1.8	74	1.2	
Diagnosis	Appendicitis with localized peritonitis and other/ unspecified appendicitis	8737	81	5465	87	<0.001
	Acute appendicitis with generalized peritonitis	490	4.5	169	2.7	
	Acute appendicitis with perforation or rupture	1305	12	512	8.2	
	Acute appendicitis with peritoneal abscess	307	2.8	121	1.9	

ASA, American Society of Anesthesiologists classification system; n.s., not significant; SD, Standard Deviation.

data entry. Furthermore, we did not have access to other relevant data such as medications or details of the operative procedure. Also, the level of training (years or procedures performed) of the residents or junior attendings were not provided. Lastly, we were not able to examine long-term patient outcomes as datasets include only the index hospital stay and we have no information about the readmission rate.

In this study, there was an overall complication rate of 4.7% with a slightly better rate (4.3%) in the teaching group. The frequency of short-term complications after appendectomy in acute appendicitis differs widely. In a study of 4163 patients, complications predominately include ileus, failed weaning from the ventilator, pneumonia and wound infections occurred in 16% of the patients.[23] In another study, which was investigating the impact of training surgery on the outcome of appendectomy, the overall complication rate was 8%, regardless if the surgery was performed by a resident or an experienced surgeon.[24] In a study by Fahrner et al. which was examining 1254 appendectomies, the postoperative morbidity rate including surgical reinterventions, incisional hernia, pleural effusion and postoperative ileus was 2.6% overall, but interestingly, lower in patients who were operated by resident surgeons (1.8%) than those who underwent surgery by attending surgeons (3.7%).[14] The authors of this study believe that the lower postoperative complication rate

TABLE 2. Teaching YES or No, Procedure Characteristics

Parameter		Teaching NO (n = 10,839)		Teaching YES (n = 6267)		p Value
		n	%	N	%	
Surgeon class	Senior attending	4151	38	221	3.5	<0.001
	Junior attending	5504	51	1419	23	
	Resident	1184	11	4627	74	
Type of surgery	Laparoscopically	9704	90	4981	79	<0.001
	Conversion	866	8.0	1087	17	
	Open	269	2.5	199	3.2	
Duration surgery (minutes)	Mean ± SD	62 ± 46		69±48		<0.001
Complications	Yes	538	5.0	269	4.3	0.025
Thromboembolism prophylaxis	Thromboembolism prophylaxis	8805	81	5256	84	<0.001
	No thromboembolism prophylaxis	1924	18	960	15	
	Anticoagulation	110	1.0	51	0.81	
Antibiotics	No antibiotics	267	2.5	133	2.1	<0.001
	Prophylactic antibiotics	7224	67	4632	74	
	Antibiotic therapy	3348	31	1502	24	

SD, standard deviation.

TABLE 3. Predictors of Complications

Parameter	Sig.	OR	95% C.I. for EXP(B)	
			Lower	Upper
ASA V (vs. ASA I)	0.743	3.343	0.002	4509
ASA IV (vs. ASA I)	0.033	2.523	1.076	5.915
Anticoagulation (vs. thromboembolism prophylaxis)	<0.001	2.290	1.453	3.609
Open (vs. laparoscopically)	<0.001	1.827	1.311	2.546
Comorbidity yes (vs. comorbidity no)	<0.001	1.635	1.265	2.112
ASA III (vs. ASA I)	0.002	1.567	1.172	2.096
Intubation yes (vs. intubation no)	0.037	1.457	1.022	2.076
Acute appendicitis with generalized peritonitis (vs. acute appendicitis with peritoneal abscess)	0.091	1.404	0.947	2.080
Antibiotic therapy (vs. no antibiotics)	0.271	1.354	0.789	2.323
ASA II (vs. ASA I)	0.027	1.219	1.023	1.452
Length of stay preoperative (days)	<0.001	1.210	1.153	1.270
Conversion (vs. laparoscopically)	0.202	1.158	0.924	1.451
Gender male (vs. female)	0.094	1.141	0.978	1.331
Acute appendicitis with perforation or rupture (vs. acute appendicitis with peritoneal abscess)	0.952	1.011	0.706	1.448
Duration ICU (hours)	0.001	1.008	1.003	1.013
Age (years)	0.001	1.007	1.003	1.012
Duration surgery (minutes)	<0.001	1.006	1.004	1.007
No thromboembolism prophylaxis (vs. thromboembolism prophylaxis)	0.733	0.960	0.757	1.217
Appendicitis with localized peritonitis and other/unspecified appendicitis (vs. acute appendicitis with peritoneal abscess)	0.009	0.630	0.444	0.892
Prophylactic antibiotics (vs. no antibiotics)	0.050	0.586	0.343	1.001

OR: Odds ratio a. Variable(s) entered on step 1: Alter_berechnet, Tage_prae_op_berechnet, IPS_Dauer_berechnet, Operationsdauer_berechnet, Geschlecht_berechnet, ASA_Risiko_berechnet, Klasse_berechnet, Nebendiagnose_berechnet_YES_NO, Beatmung_berechnet, Hauptdiagnose_berechnet, Operateurklasse_berechnet, Lap_offen_berechnet, ThromboembolieProphylaxe_berechnet, AB_Therapie_berechnet_neu, Teaching_berechnet.

TABLE 4. Predictors of Mortality (Bivariate Analysis)

Parameter		Survivors (n = 17,077)		Nonsurvivors (n = 29)		p Value
		N	%	n	%	
Age (years)	Mean ± SD	37 ± 19		51 ± 25		<0.001
ASA	I (Healthy person)	9850	58	14	48	<0.001
	II (Mild systemic disease)	6403	37	5	17	
	III (Severe systemic disease)	789	4.6	6	21	
	IV (Severe systemic disease that is a constant threat to life)	33	0.19	3	10	
	V (Moribund person who is not expected to survive without the operation)	2	0.012	1	3.4	
Length of stay preoperative (days)	Mean ± SD	0.37 ± 1.0		1.1 ± 3.0		0.002
Duration ICU (hours)	Mean ± SD	0.69 ± 11		114 ± 251		<0.001
Intubation	Yes	487	2.9	7	24	<0.001
Diagnosis	Appendicitis with localized peritonitis and other/unspecified appendicitis	14182	83	20	69	<0.001
	Appendicitis (acute) with generalized peritonitis	653	3.8	6	21	
	Acute appendicitis with perforation or rupture	1815	11	2	6.9	
	Acute appendicitis with peritoneal abscess	427	2.5	1	3.4	
Type of surgery	Laparoscopically	14664	86	21	72	0.026
	Conversion	1949	11	4	14	
	Open	464	2.7	4	14	
Duration surgery (minutes)	Mean ± SD	65 ± 46		153 ± 203		<0.001
Complications	Yes	792	4.6	15	52	<0.001
Antibiotics	No antibiotics	400	2.3	0	0	0.019
	Prophylactic antibiotics	11842	69	14	48	
	Antibiotic therapy	4835	28	15	52	
Teaching	Yes	6256	37	11	38	n.s.

ASA, American Society of Anesthesiologists classification system; n.s., not significant; SD: standard deviation.

TABLE 5. Predictors of Teaching

Parameter	Sig.	OR	95% C.I. for EXP(B)	
			Lower	Upper
Insurance status statutory (vs. private)	<0.001	4.430	3.920	5.007
Conversion (vs. laparoscopically)	<0.001	2.515	2.276	2.779
Comorbidity no (vs. comorbidity yes)	<0.001	1.662	1.416	1.950
Open (vs. laparoscopically)	<0.001	1.507	1.242	1.829
Appendicitis with localized peritonitis and other/unspecified appendicitis (vs. acute appendicitis with peritoneal abscess)	0.001	1.465	1.173	1.831
Intubation no (vs. intubation yes)	0.001	1.433	1.168	1.758
ASA II (vs. ASA IV)	0.486	1.313	0.610	2.823
ASA I (vs. ASA IV)	0.691	1.168	0.543	2.515
ASA III (vs. ASA IV)	0.770	1.123	0.515	2.448
Acute appendicitis with perforation or rupture (vs. acute appendicitis with peritoneal abscess)	0.910	1.014	0.795	1.293
Age (years)	0.053	0.998	0.996	1.000
Acute appendicitis with generalized peritonitis (vs. acute appendicitis with peritoneal abscess)	0.351	0.874	0.658	1.160

OR, odds ratio.

of the residents' group was due to selection bias since the patients with poor preoperative conditions, severe appendicitis, and concomitant diseases were automatically assigned to the group treated by attending surgeons. We found that pre-existing comorbidities, higher ASA-score, higher age and longer operation were significant predictors for complications. Residents and young consultants in this study rather operated on healthier patients explaining the lower complication rate in the teaching group. Teaching itself was not a predictor in multivariate analysis in our study.

This study did not show a significant difference in mortality between the teaching and the nonteaching group. We found an overall mortality following appendectomy of 0.17%, which was slightly worse than mortality rates in studies from Germany (0.07%) and the United States (0.11%) but better than studies from Sweden and Denmark (0.25%) and a large study including 164,579 appendectomies from Finland (0.21%).[25–29] Several previous studies have shown no difference in mortality as a function of teaching status, which is consistent with the findings of our present study.[14,30–36] Mortality after appendectomy is associated with higher age, open appendectomy, complicated appendectomy, male sex, postsurgical complications, higher ASA-Score and comorbidities such as diabetes, cardiovascular disease and COPD.[23,27,29,37] In line with such reports, higher age, comorbidities, complications, higher ASA-score and complicated appendicitis were associated with mortality in our dataset.

In our study, 6267 cases (37%) of all appendectomies observed, were performed by residents. Predictors for assignment to the teaching group were statutory insurance status, absence of comorbidities, younger age and noncomplicated appendicitis. These factors may explain the slightly lower complication rate recorded in the teaching group.

There were a significant higher number of patients with statutory insurance (vs. private) in the teaching group. These socioeconomic differences have been observed in different countries.[38,39]

The shorter LOS for teaching operations of 3.2 days (3.6 days for no-teaching) is also reflected in the literature with 3.9 days vs. 4.8 days in the retrospective evaluation of 1197 cases by Fahner et al.[14] However other studies by Wonkyeong et al. and Baha et al. observed no difference in length of stay regarding the teaching status[32,35]

We found significant longer operation times in the residents' group which is consistent to previous studies and obviously reflects the learning curve. There is a presumption that is supported by our data that sicker patients (higher ASA score) with more comorbidities as well as more complex cases (perforations, peritonitis or abscesses) were treated in the majority of the no teaching group.[14,32,35] With regard to the rate of abdominal previous operations there was no significant difference between the no-teaching and the teaching group.[40] The database did not provide the information of costs, therefore we could not evaluate the effects of teaching on costs of extra time in the operation room. Several other studies however have shown that teaching is time-consuming and suggests higher costs associated with teaching operations in general.[9,10,41,42] In a subanalysis eliminating nonresident teaching cases, similar results were revealed.

CONCLUSIONS

Teaching had no direct influence on complication or in-hospital mortality rate of appendectomy. Only a prolonged duration of the procedure was observed. The no teaching group showed a shorter duration of surgery but a longer length of stay despite the more severe stage of appendicitis, higher age and increased rate of comorbidities. The advantages of teaching in the surgical setting are superior and justifiable.

ETHICAL REVIEW COMMITTEE STATEMENT

The data of this study are based on anonymized, de-identified data; our institutional review board waves the necessity of institutional review board approval.

CONFLICTS OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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